

Measurement of the electromagnetic dissociation cross section of Pb nuclei at $\sqrt{s_{\text{NN}}} = 2.76 \text{ TeV}$

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Abstract. Electromagnetic dissociation of heavy nuclei in ultra-peripheral interactions at high energies can be used to monitor the beam luminosity at colliders. In ALICE neutrons emitted by the excited nuclei close to beam rapidity are detected by the Zero Degree Calorimeters (ZDCs), providing a precise measurement of the event rate. During the 2010 Pb run, a dedicated data taking was performed triggering on electromagnetic processes with the ZDCs. These data, combined with the results from a Van der Meer scan, allowed to measure the electromagnetic dissociation cross-section of Pb nuclei at $\sqrt{s_{\text{NN}}} = 2.76 \text{ TeV}$. Experimental results on various cross-sections are presented together with a comparison to the available predictions.

In ultra-peripheral collisions, for which the impact parameter is larger than the sum of the two nuclear radii, the interaction occurs via electromagnetic (EM) forces. These interactions are usually described in the framework of the Weizsäcker-Williams method [1]. At the LHC the cross section for EM processes exceeds the hadronic cross section by several order of magnitude (see [2] for updated predictions). EM processes will therefore strongly limit the beam lifetime. In electromagnetic dissociation (EMD) interactions the nucleus is excited by the absorption of one or two photons (mainly in the Giant Dipole Resonance region). For heavy nuclei single neutron (1n) emission is the main decay mechanism. The emitted neutrons have a rapidity close to the beam one, therefore the Zero Degree Calorimeters (ZDCs) are ideal devices for their detection. The ALICE experiment has two neutron ZDCs (ZNs), placed on both sides relative to the interaction point (IP), about 114 m away from it. In addition, for the present analysis, signals from two small EM calorimeters (ZEMs) were also used. These detectors are placed only on one side with respect to the IP, at about 7.5 m from it, covering the $4.8 < \eta < 5.7$ region (see [3] for a detailed description of the ALICE ZDCs).

The analyzed data sample ($\sim 3 \times 10^6$ events) was collected in a dedicated run during 2010 Pb data taking. The trigger condition required a signal either in A side ZN (ZNA) or in C side ZN (ZNC), selecting thus single EMD[‡] as well as hadronic interactions. Requiring the coincidence of the signal in the two ZNs, only mutual EMD processes and hadronic interactions are selected (fig. 1).

[‡] Single EMD indicates interactions in which at least 1n is emitted by one of the two nuclei. In mutual EMD processes both nuclei emits at least 1n (single EMD includes therefore mutual EMD).

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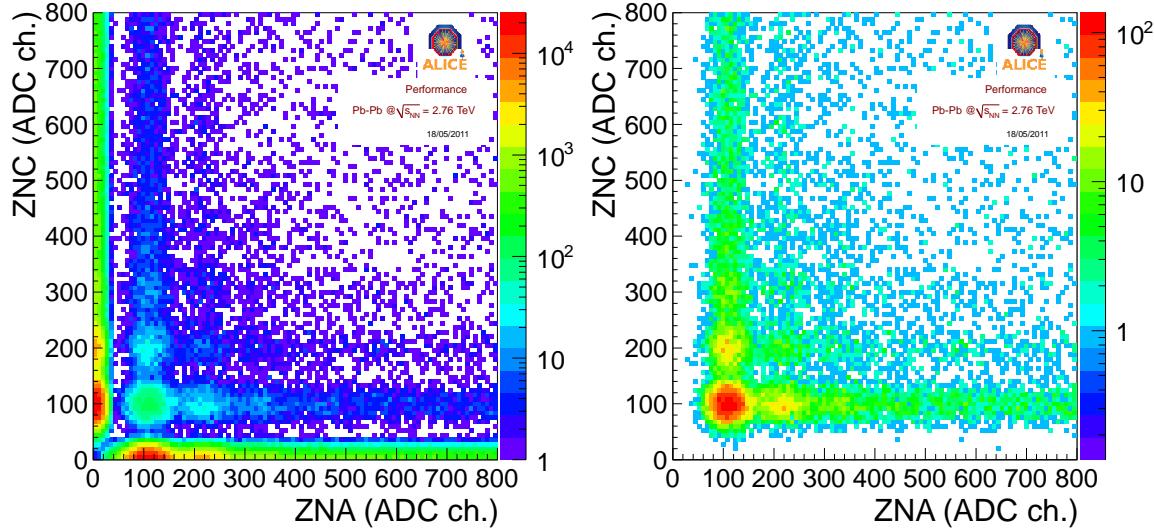


Figure 1. Left: ZNC vs. ZNA signal for single EMD events. Right: ZNC signal vs. ZNA signal for mutual EMD events (single neutron signal is at ADC channel 100).

Table 1. Preliminary results from the van der Meer scan for three ZDC trigger inputs.

ZDC trigger	Process	$\sigma_{vdM}(b)$
ZNC OR ZNA	2×single EMD - mutual EMD + hadronic	362.61 ± 0.02 stat. $^{+39.89}_{-10.88}$ syst.
(ZNC AND ZNA) AND NOT (ZEM1 OR ZEM2)	mutual EMD	5.91 ± 0.18 stat. $^{+0.65}_{-0.18}$ syst.
(ZNC AND ZNA) AND (ZEM1 OR ZEM2)	hadronic	7.08 ± 0.15 stat. $^{+0.78}_{-0.21}$ syst.

Data from a van der Meer (vdM) scan [4] have also been used. During the scan different ZDC trigger inputs have been used to select various processes (as reported in table 1). The vdM scan results are still preliminary, in particular the systematic error estimate. The main contribution to the systematic errors are: $\pm 4\%$ from systematic uncertainties associated with the ALICE measurement (see [5] for a complete description of the sources), $\pm 3\%$ from beam current measurement and $-0\% / +11\%$ from the ghost charge \S fraction evaluation. The main contribution to the systematic error on cross section calculation is therefore presently due to the error on absolute cross section measurements from the vdM scan.

The model used for comparison is the Relativistic Electromagnetic DISsociation (RELDIS) [6, 7], in which the EM dissociation of ultra-relativistic heavy ions is treated including both single and double virtual photon absorption. The EMD cross section predictions for Pb-Pb interactions at $\sqrt{s_{NN}} = 2.76$ TeV are: $\sigma^{sEMD} = (185.2 \pm 9.2)$ b for single EMD, $\sigma^{mEMD} = (5.5 \pm 0.6)$ b for mutual EMD processes. The error on the calculated single EMD cross section also includes the systematic error estimated as the difference between the RELDIS result and the calculations by other authors [8].

\S The amount of charge outside the nominal buckets.

Fig. 2 shows the two ZN signal amplitude spectra. The superimposed fit is given by the sum of 6 Gaussians. The curves for the pedestal (corresponding to neutron emission on the other side) and for the 1n peak have three free parameters, while the following Gaussians have a constraint both on the mean value (fixed to be i times the 1n mean value for i^{th} peak) and on the width (to take into account that the pedestal width affects the width of the Gaussian signals).

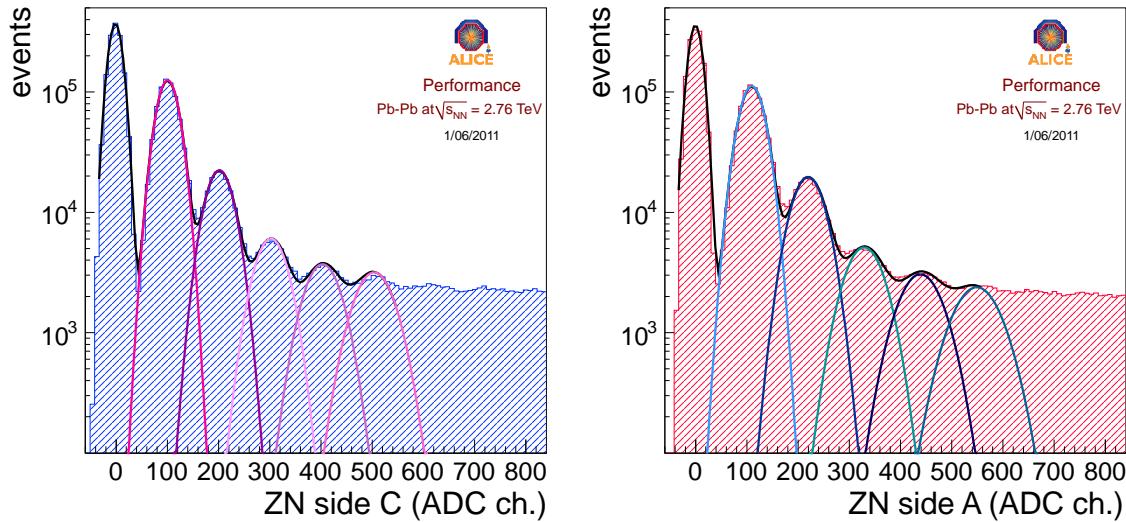


Figure 2. ZNC (left) and ZNA (right) spectra (event selection: ZNC or ZNA).

For hadronic interactions, both ZNs have a signal above threshold^{||}. Therefore, requiring to have a signal above threshold in one of the two ZN and no signal in the other one, hadronic events are rejected. The spectra with such an event selection are shown in fig. 3 together with the fit obtained by summing five Gaussians, similarly to what described above. For both selections the cross section for the selected process can be estimated using the absolute values measured in the vdm scan: $\sigma^{proc} = \sigma_{vdm} \times N^{proc}/N_{tot}$, where N^{proc} is the number of events in our sample for the selected process and N_{tot} is the total number of events collected with the same trigger used to determine σ_{vdm} . Finally the calculated values are corrected for ZN acceptance[¶].

The mutual EMD cross section calculation is much more delicate since its value is comparable to the hadronic cross section value and moreover the event selection (reported in table 1) depends on the ZEM acceptance. Through Monte Carlo simulation, using RELDIS as input, we estimated that 97% of the events fulfill the chosen event selection for mutual EMD events (i.e., give no signal in ZEM). Using HIJING [9] as event generator, in 92% of the cases a minimum bias hadronic interaction gives a signal over threshold in one of the two ZEM⁺. Applying these correction factors, we estimated the contamination of hadronic events in the mutual EMD sample and then we calculated the

^{||} Threshold values are estimated to be ~ 500 GeV for ZNC and ~ 450 GeV for ZNA.

[¶] The acceptance for neutrons emitted in EMD processes at $\sqrt{s_{NN}} = 2.76$ TeV, evaluated through a Monte Carlo using RELDIS as input, is $\sim 99\%$.

⁺ The energy threshold is fixed to the experimental value: ~ 15 GeV for each ZEM.

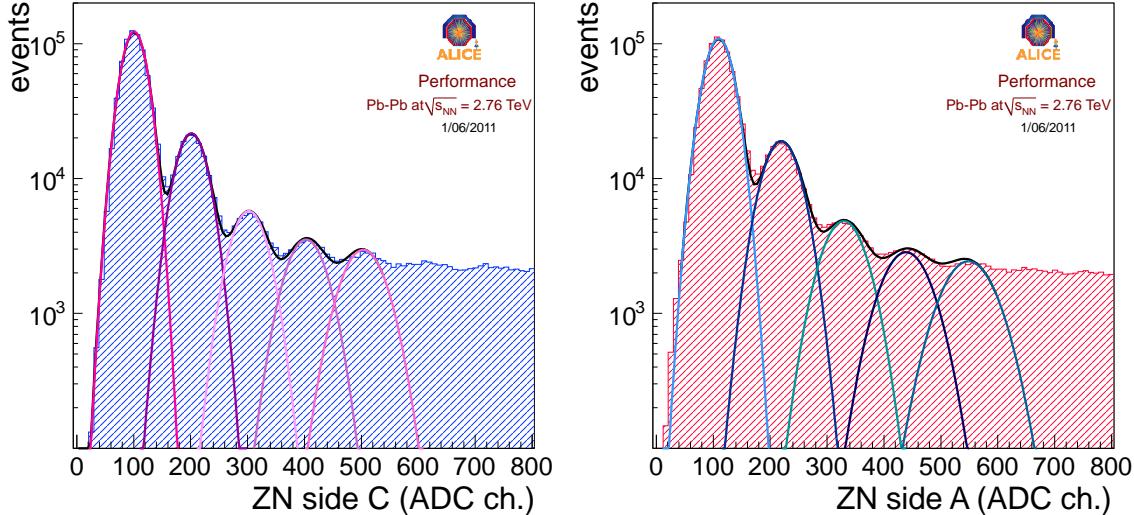


Figure 3. ZNC (left) and ZNA (right) spectra (event selection: signal in one ZN but not in the other one).

Table 2. Cross section measurements and predictions from RELDIS [7].

Process	Data σ (b)	RELDIS σ (b)
$\sigma^{sEMD} + \sigma^{had}$	195.6 ± 0.1 stat. $^{+24.2}_{-11.7}$ syst.	192.9 ± 9.2
$\sigma^{sEMD} - \sigma^{mEMD}$	176.9 ± 0.1 stat. $^{+21.6}_{-10.6}$ syst.	179.7 ± 9.2
σ^{mEMD}	5.7 ± 0.2 stat. $^{+0.7}_{-0.3}$ syst.	5.5 ± 0.6
σ^{sEMD}	185.7 ± 0.2 stat. $^{+22.6}_{-11.1}$ syst.	185.2 ± 9.2

related cross section value. The results are summarized and compared to the predictions in table 2.

Cross section values for EMD processes have been measured in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV detecting the emitted neutrons and using the absolute cross section values measured in a van der Meer scan. An excellent agreement with the predictions from the RELDIS model is found. We conclude that the ALICE ZDCs can provide a robust and independent way to monitor the LHC luminosity in heavy ion collisions by measuring the rate of emitted neutrons.

References

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